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Application of RELAP5 to Innovative Sodium Cooled Fast Reactor Design

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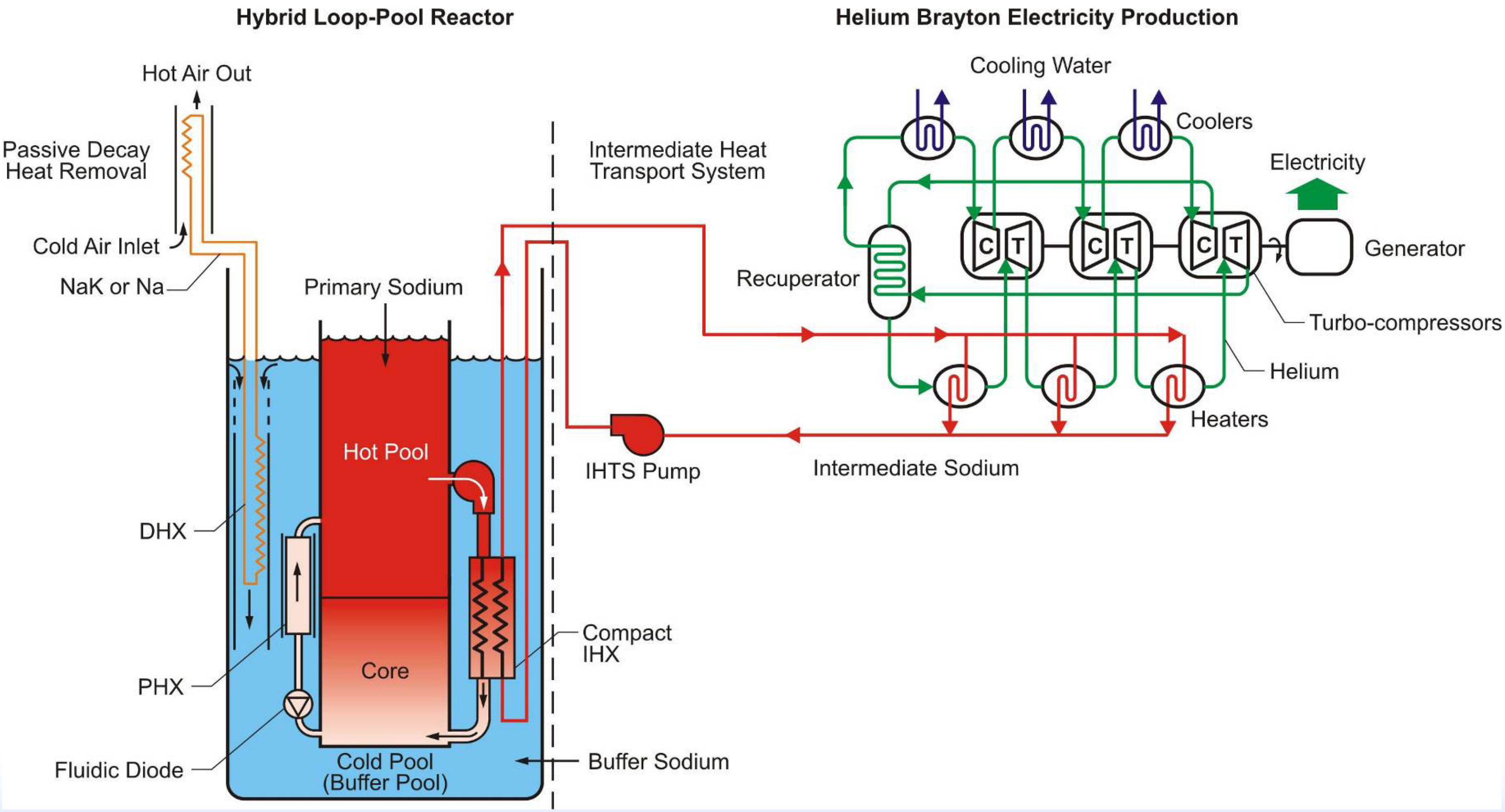
Overview

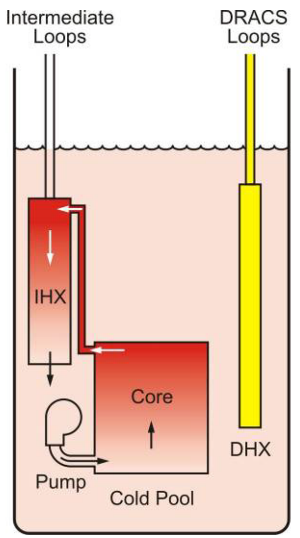
- Brief introduction of hybrid loop-pool SFR design
- LOFC analyses
- Summary and Future Work

Innovative Sodium Cooled Fast Reactor Design

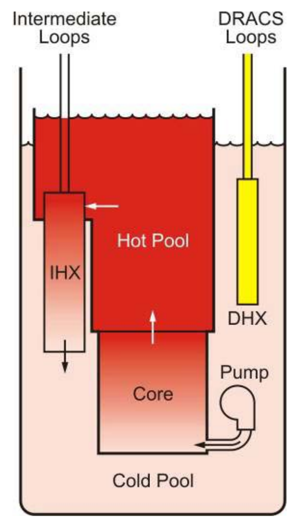
Schematic of an Advanced SFR Plant Concept



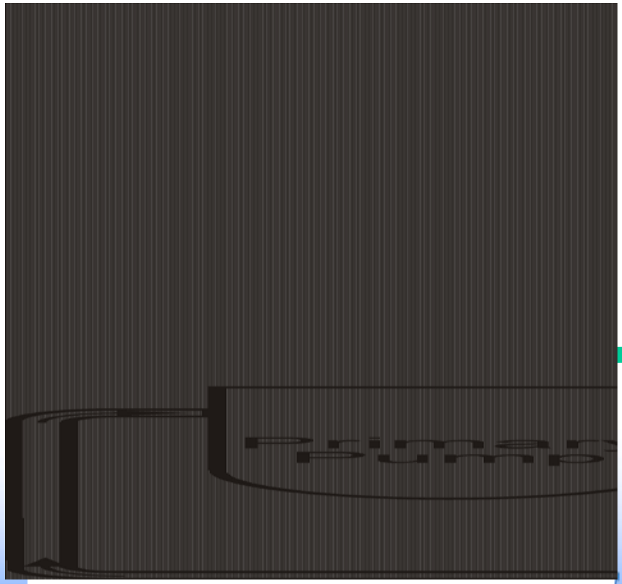
Evolution of SFR Primary System Designs



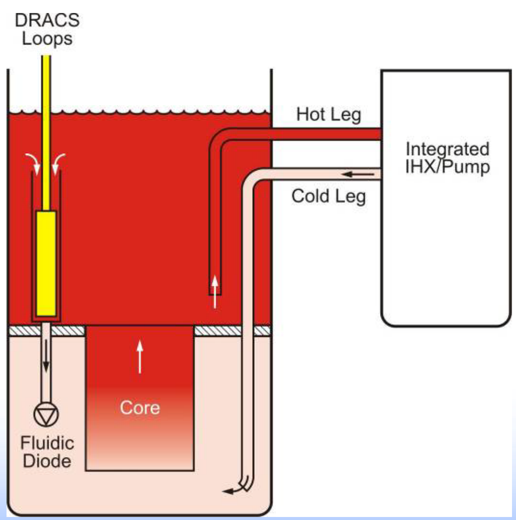
Early pool type SFR design, i.e. EBR-II



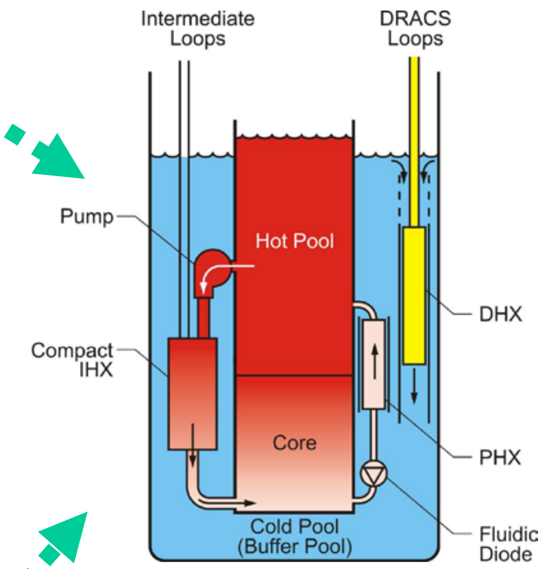
Current pool type of SFR design
i.e. EFR (EU), BN-1600 (Russia), ABR (US)



Early loop type SFR design: i.e. Monju (Japan)

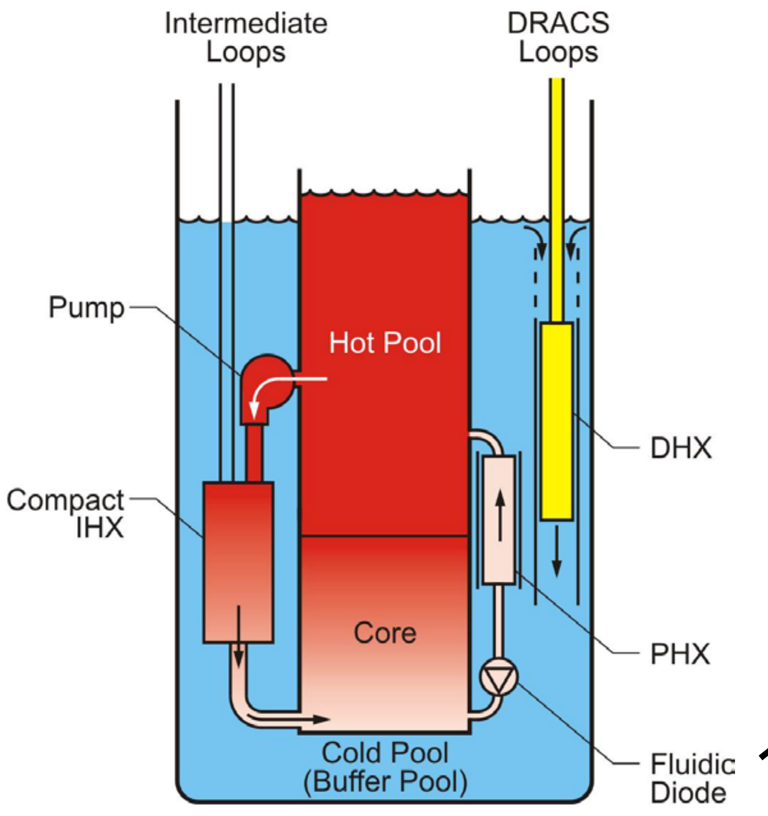


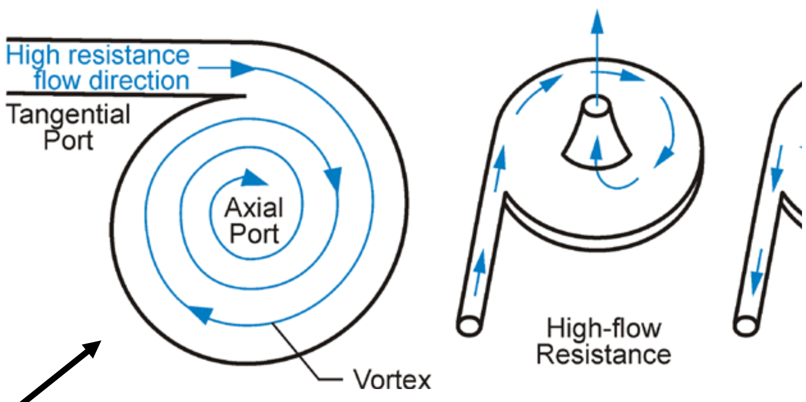
Advanced loop type of SFR design (Japan)



An innovative hybrid loop-pool design for SFR

Hybrid Loop-Pool SFR Design

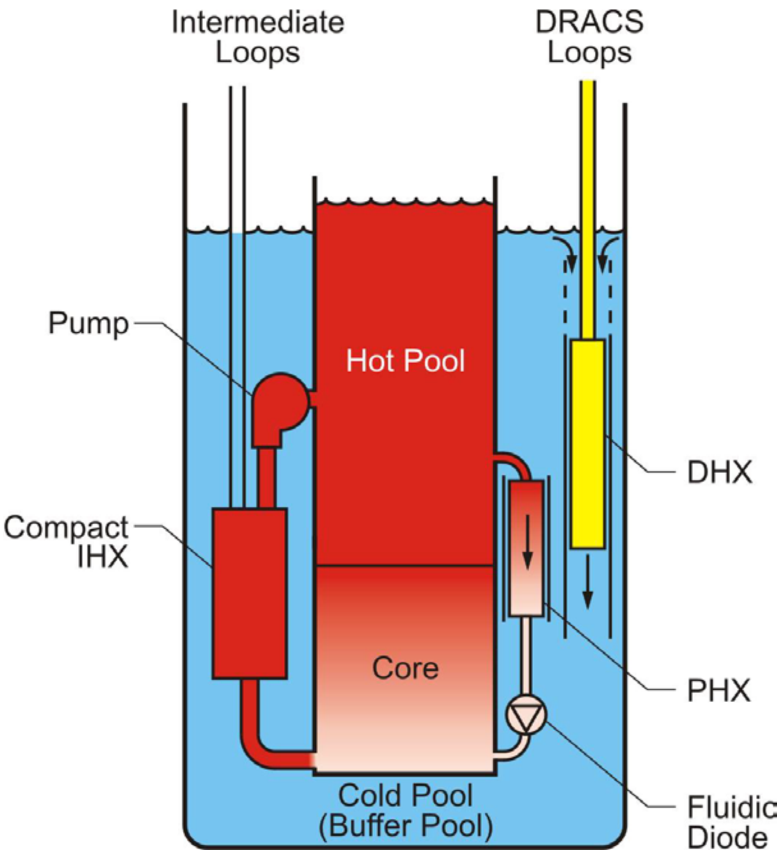


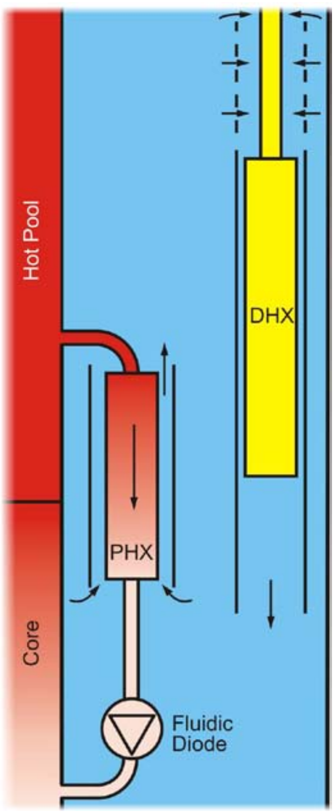


One type of fluidic diodes

An innovative hybrid loop-pool design for SFR

Hybrid Loop-Pool SFR Design: Loss of Forced Circulation





PRACS removes decay heat from primary loop to buffer pool (cold pool)

Blowup view of PRACS and DRACS

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RELAP5-3D

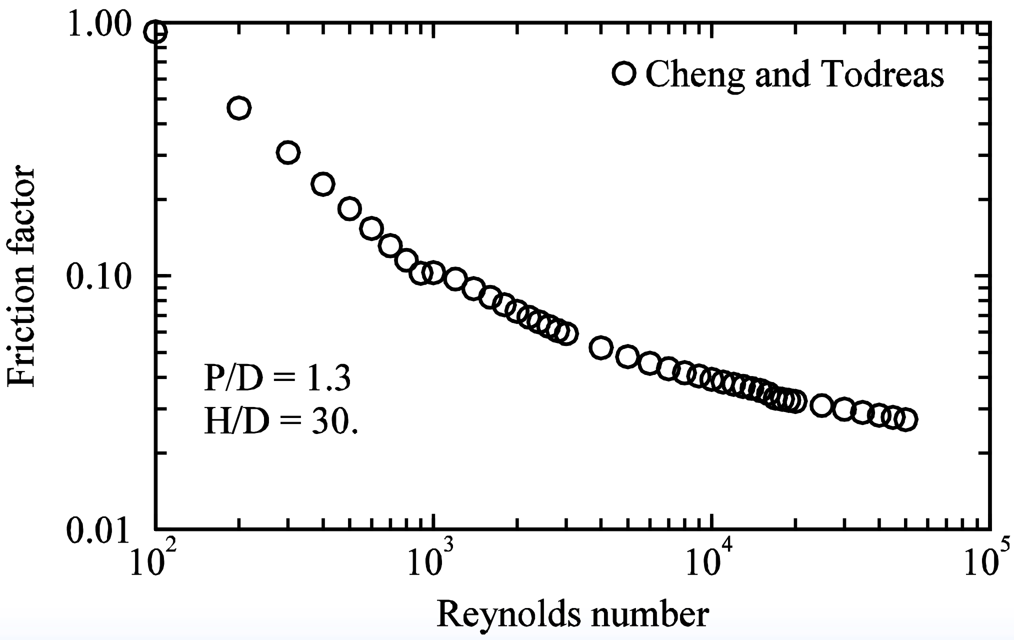
- **Generalized capability for a wide range of working fluids including liquid sodium**
- **Has been extended to analyze VHTR, liquid salt cooled AHTR, lead-bismuth cooled fast reactor, etc.**
- **Cliff Davis also assessed its applicability to SFR (INL/EXT-06-11518, INL/EXT-07-12228).**
- **MIT (Matt Memmott) has done detailed subchannel analysis for annular fuel design for SFR.**

Sodium Properties

- **Based on correlations from Fink, J. K. and L. Leibowitz, "Thermodynamic and Transport Properties of Sodium Liquid and Vapor," ANL/RE-95/2, January 1995.**

Correlations – Frictional Characteristics

- **Cheng-Todreas correlation for wire wrapped pin bundles (Nuclear Engineering & Design, 92 (1986) 227-251)**



Correlations – Heat Transfer

- **Within the core - Rod Bundle correlation with liquid metals developed by Westinghouse**

$$Nu = 4.0 + 0.33(P/D)^{3.8}(Pe/100)^{0.86} + 0.16(P/D)^{5.0}$$

- **Outside the core - RELAP5 default single phase heat transfer correlation for liquid metal**

$$Nu = 5.0 + 0.025Pe^{0.8}$$

Protected Loss of Flow Transient (PLOF)

LOFC with Scram (PLOFC) Analysis

- **Reactor analyzed: 250 MWth design**
  - **The total masses and thermal capacities of the primary loops and cold pool as well as the core design are referred to the ANL ABTR design (Y. I. Chang, et. al., 2006. “Advanced Burner Test Reactor Preconceptual Design Report”, Argonne National Laboratory report ANL-ABR-1 (ANL-AFCI-173)).**
  - **The PHX modules are sized with a nominal heat removal ability at 1.3% of normal reactor power , and the DHX with a capacity of 0.7% of normal reactor power.**
  - **Reactor inlet/outlet temperatures are 355 C/510 C; buffer pool average temperature is set at 355 C.**

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Core Model (reference: ANL-ABR-1)

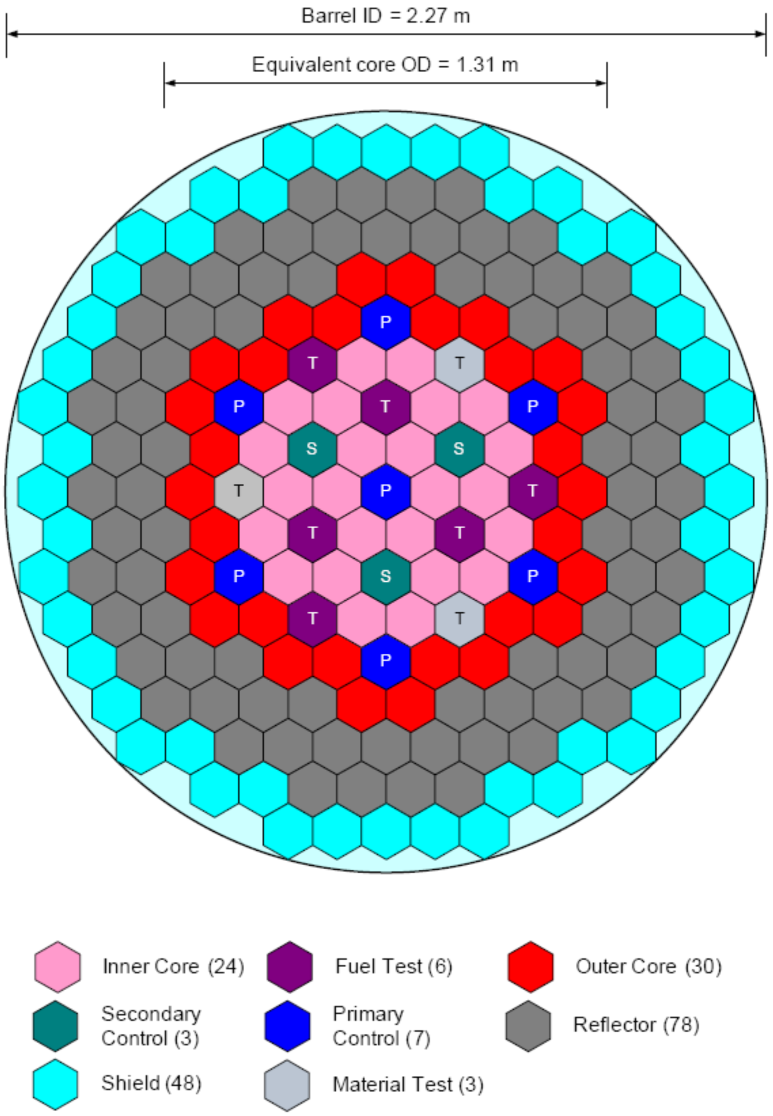
24 Inner & 30 Outer core Assemblies

TRU=16.5 & 20.7%

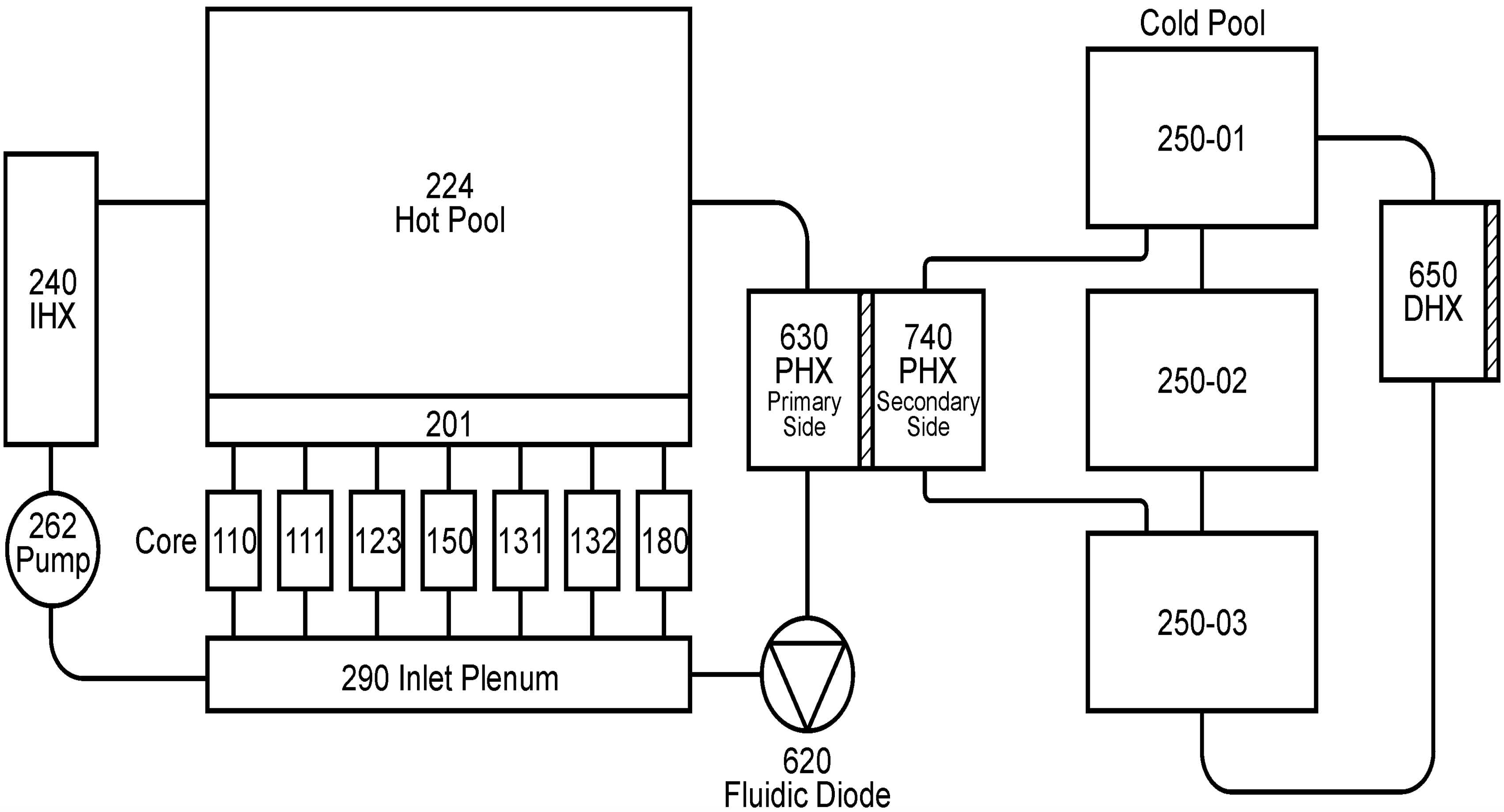
BOEC as the SS condition for transients

Flow Channels – 1D Model

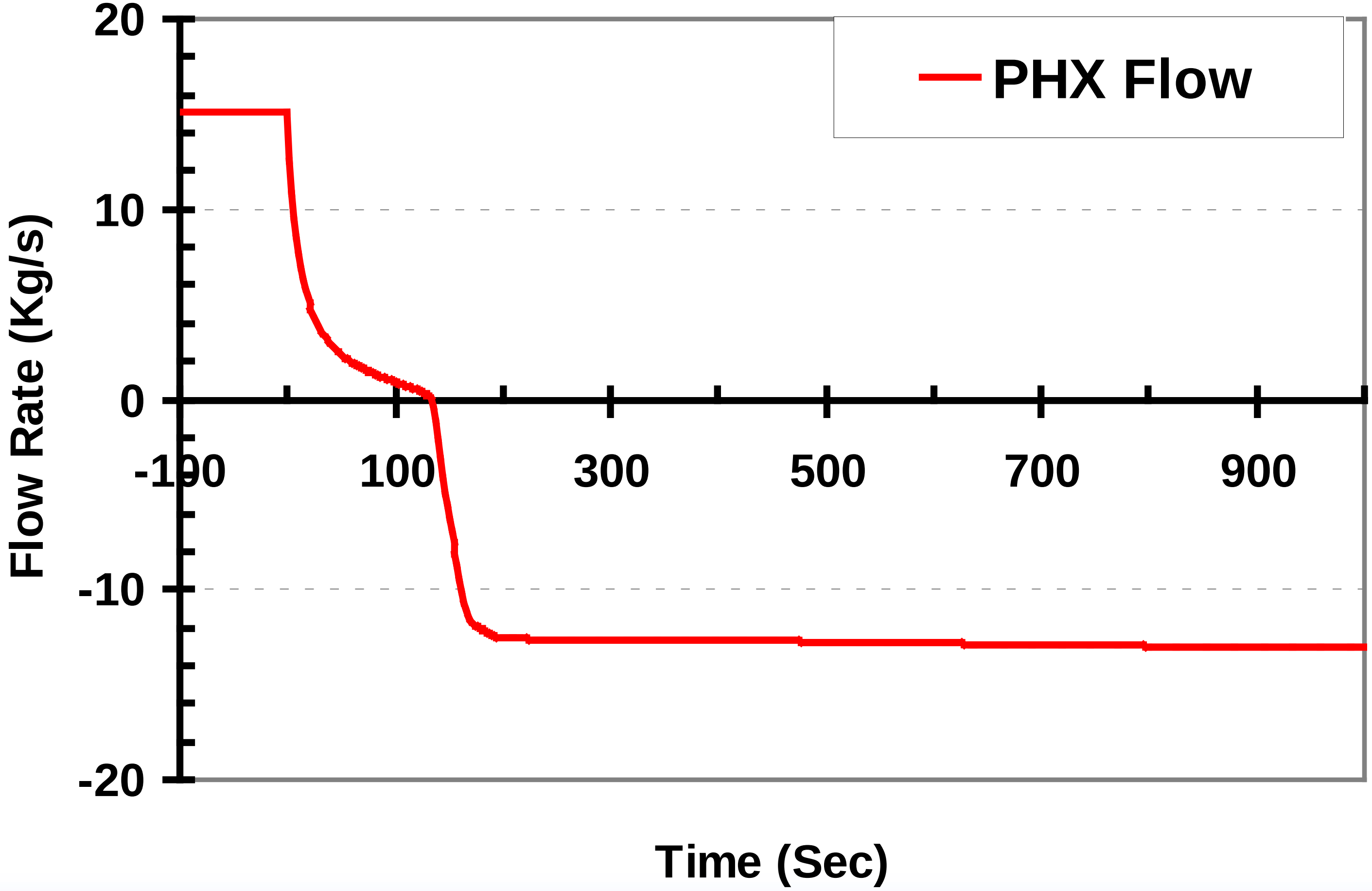
- Hot assembly
- Averaged inner driver assemblies
- Averaged outer driver assemblies
- Averaged control assemblies
- Averaged reflectors
- Averaged Shields
- Bypass



RELAP5-3D Model for SFR-Hybrid



PHX Flow During PLOFC



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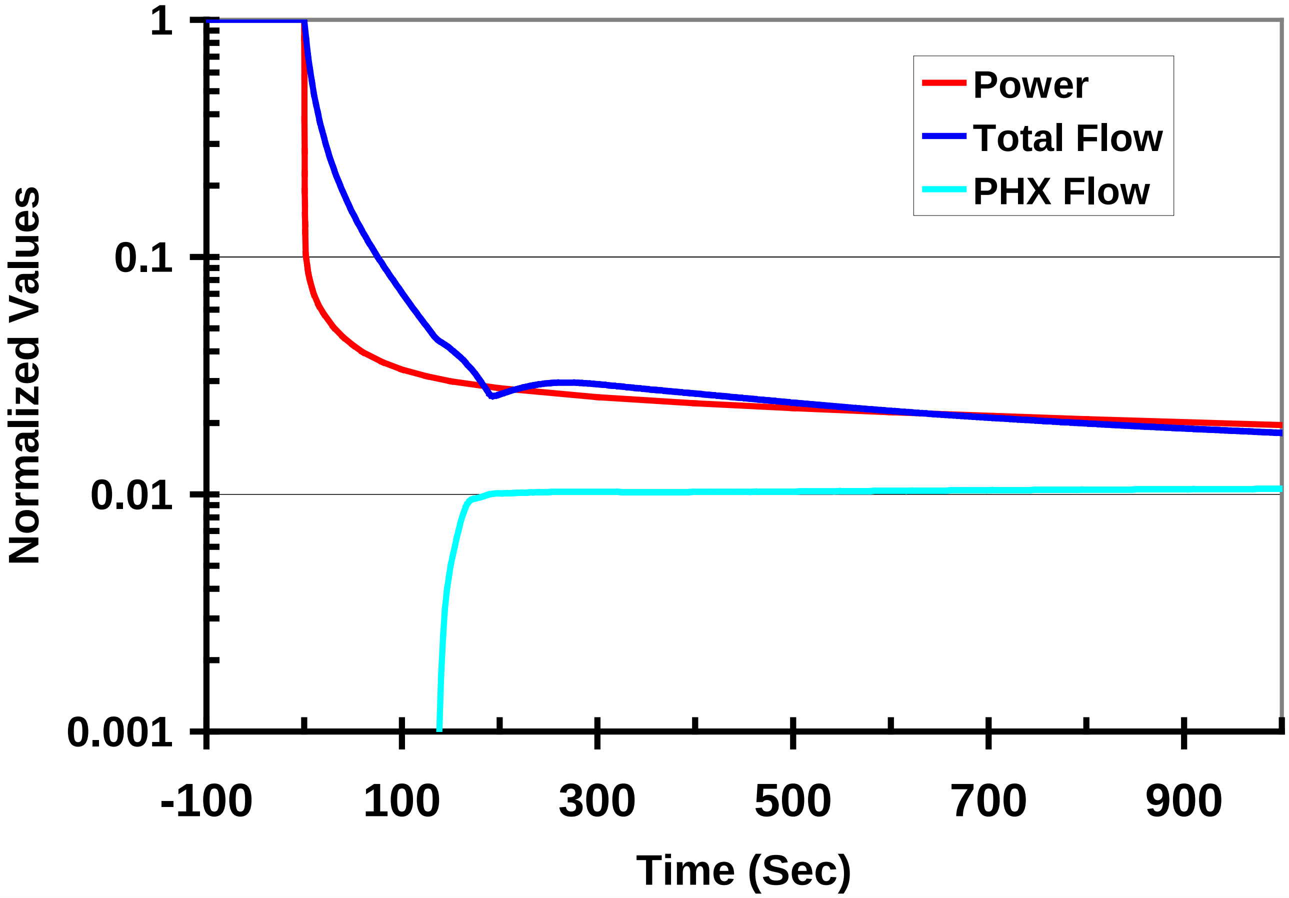
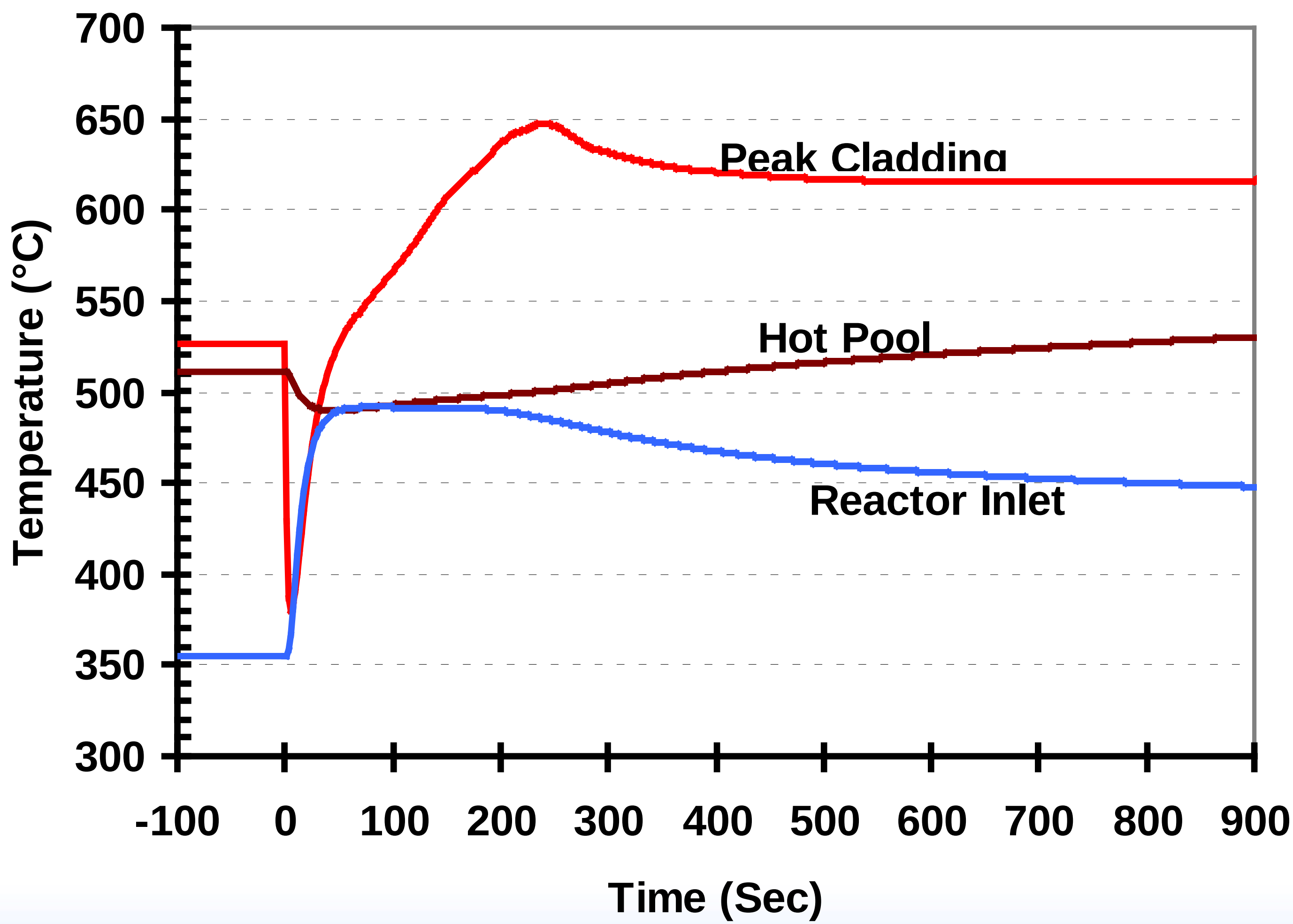
Normalized Power and Flow during PLOFC



Temp. Response of the Hybrid SFR to PLOFC



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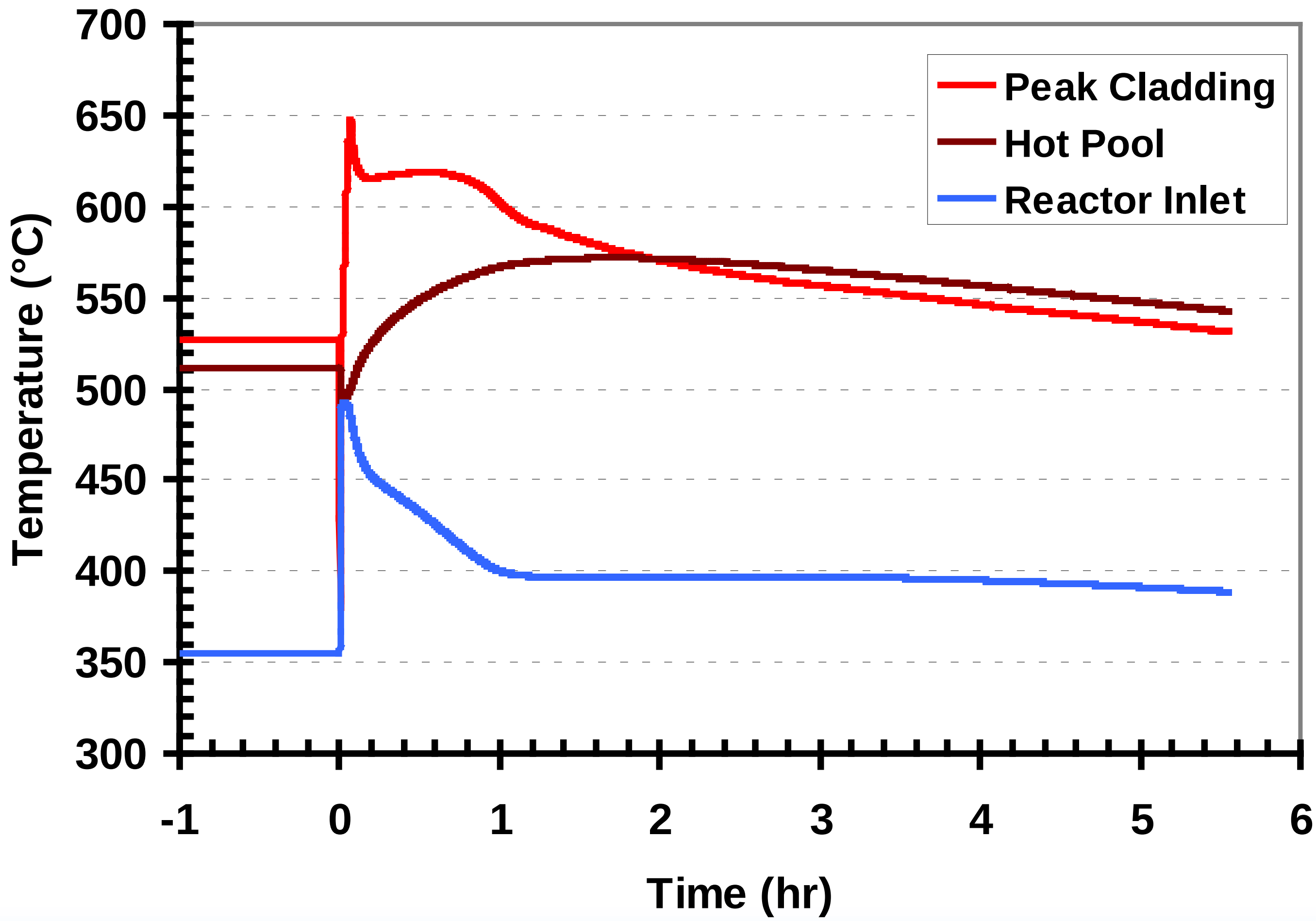
Long Term Temp. Response of the Hybrid SFR to PLOFC



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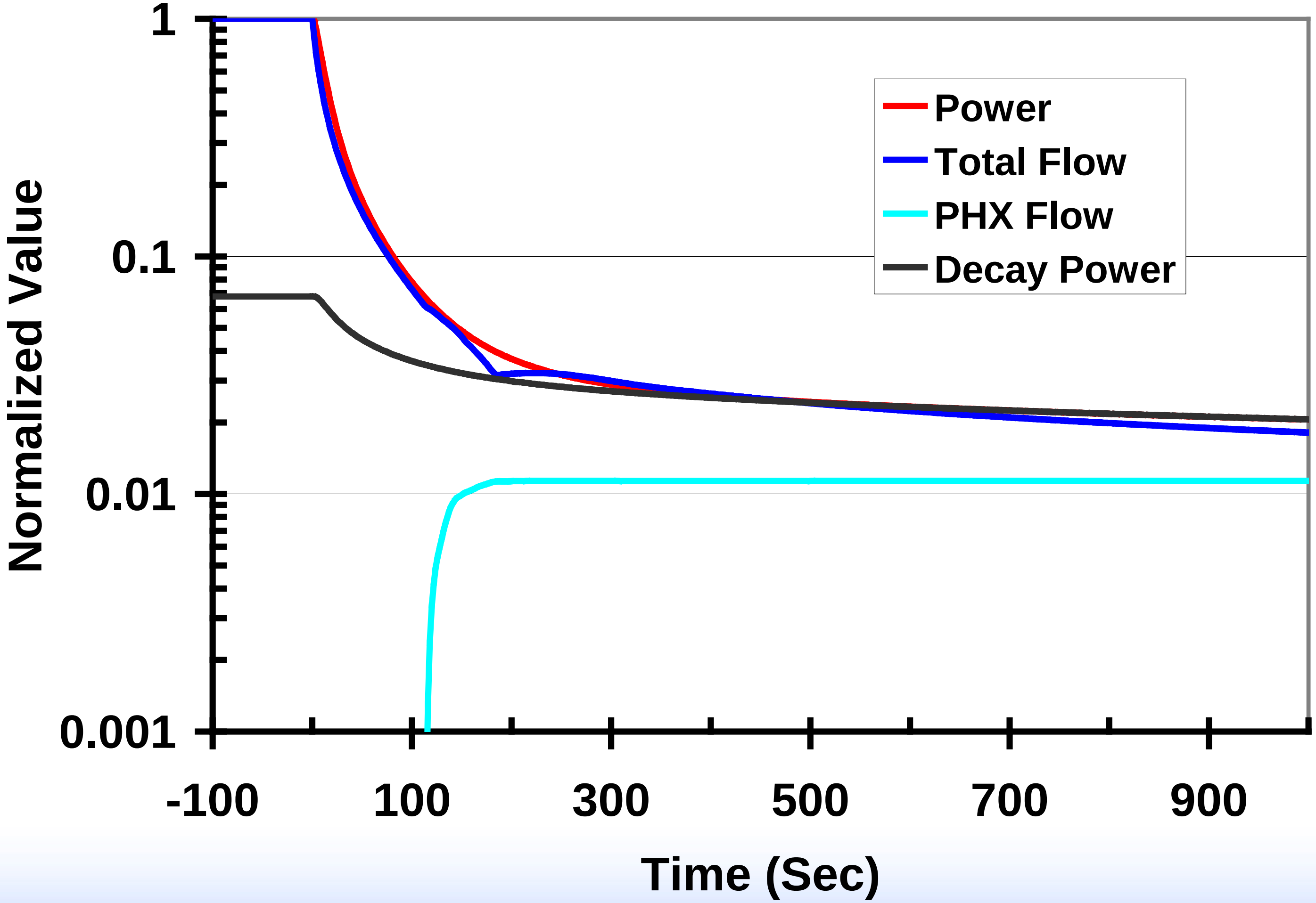
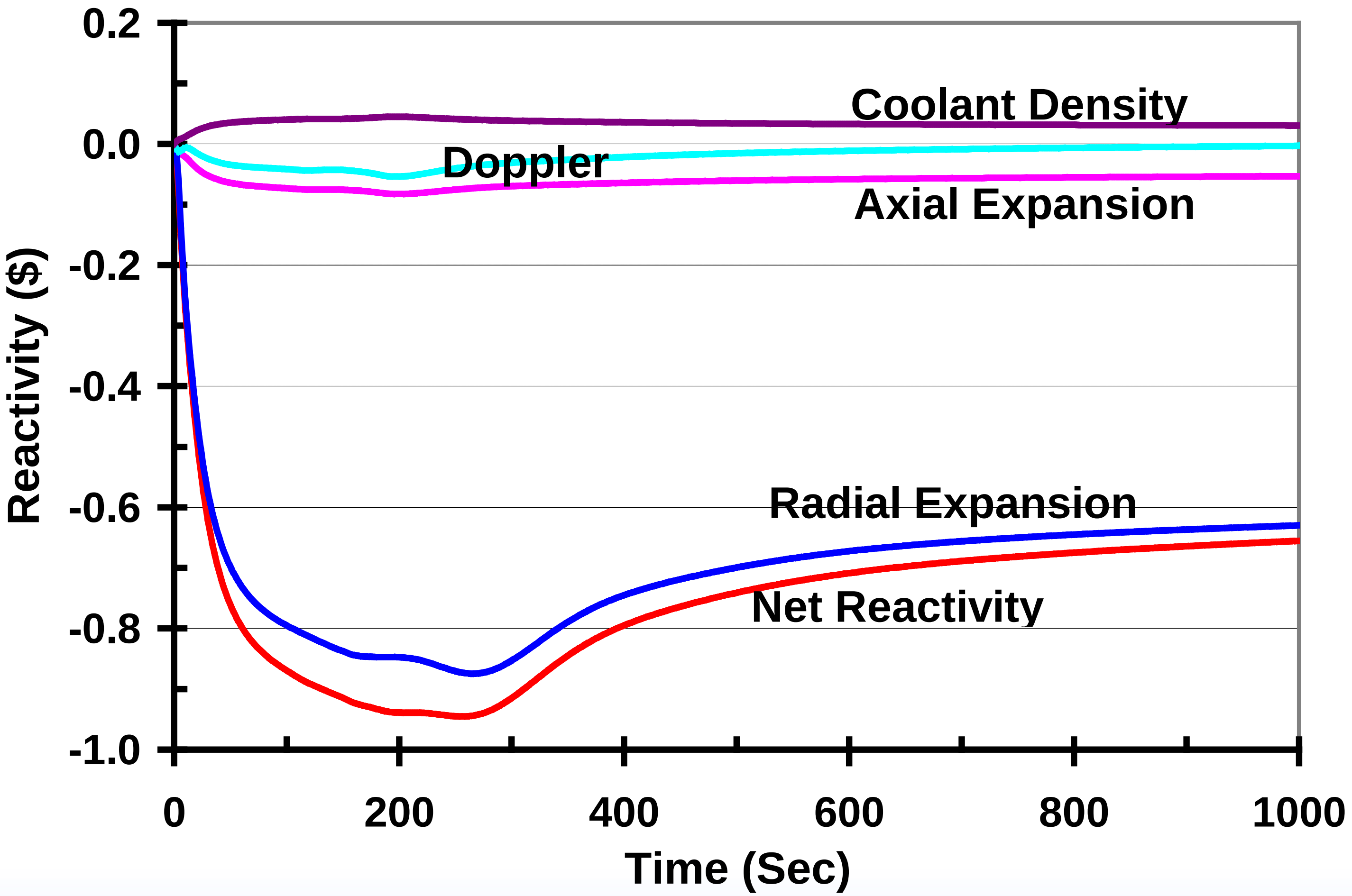
Unprotected Loss of Flow Transient (ULOF)

Normalized Power and Flow during ULOF



Reactivity Response



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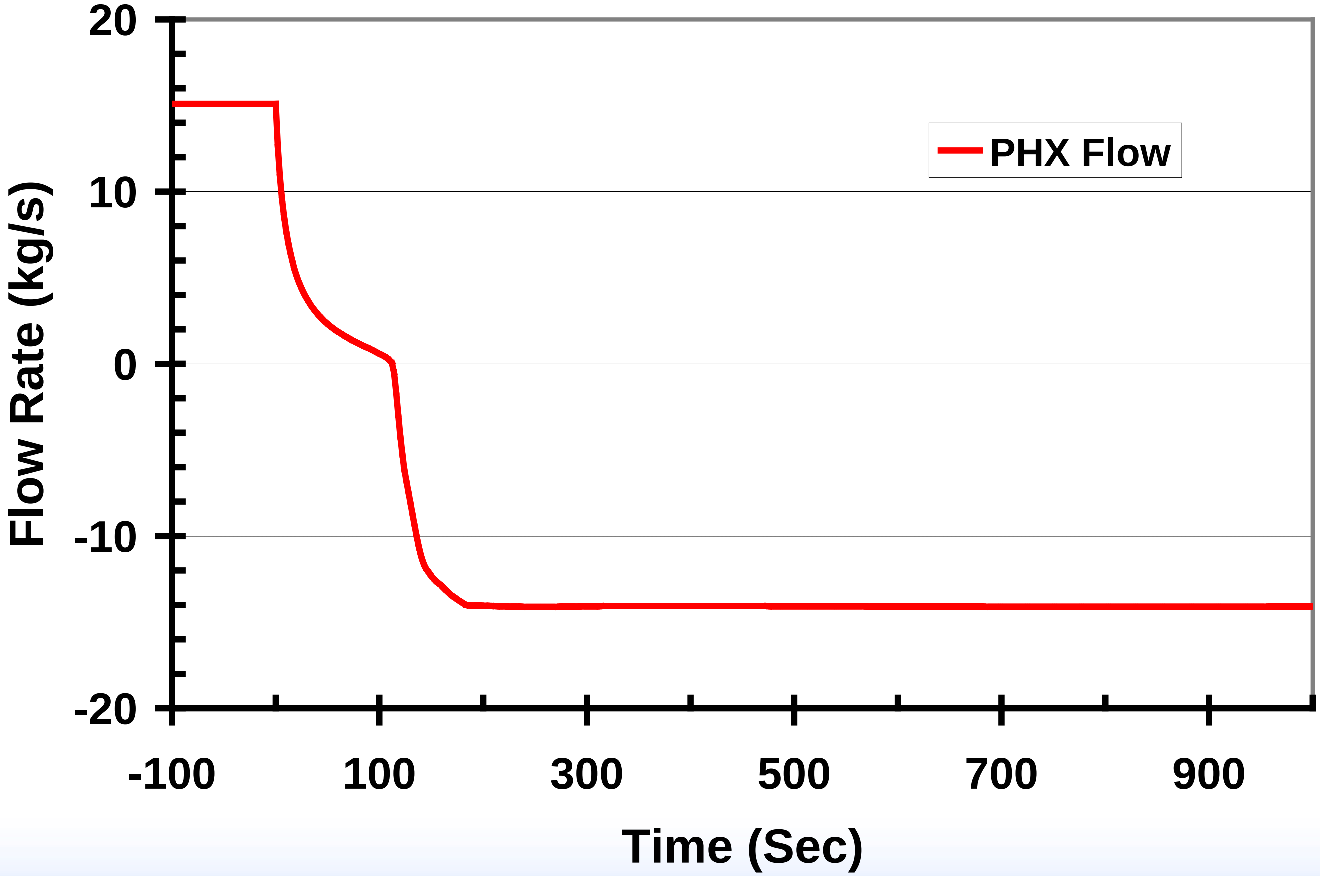
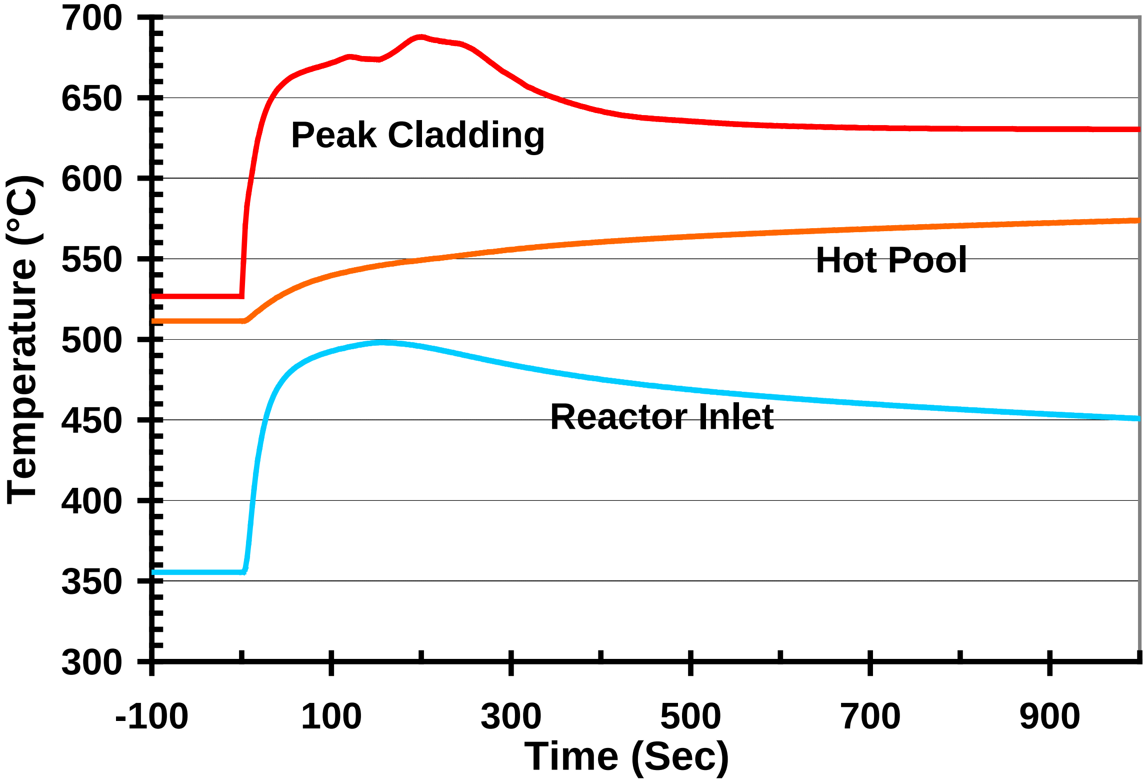
PHX Flow During ULOF



Temp. Response of the Hybrid SFR to ULOF



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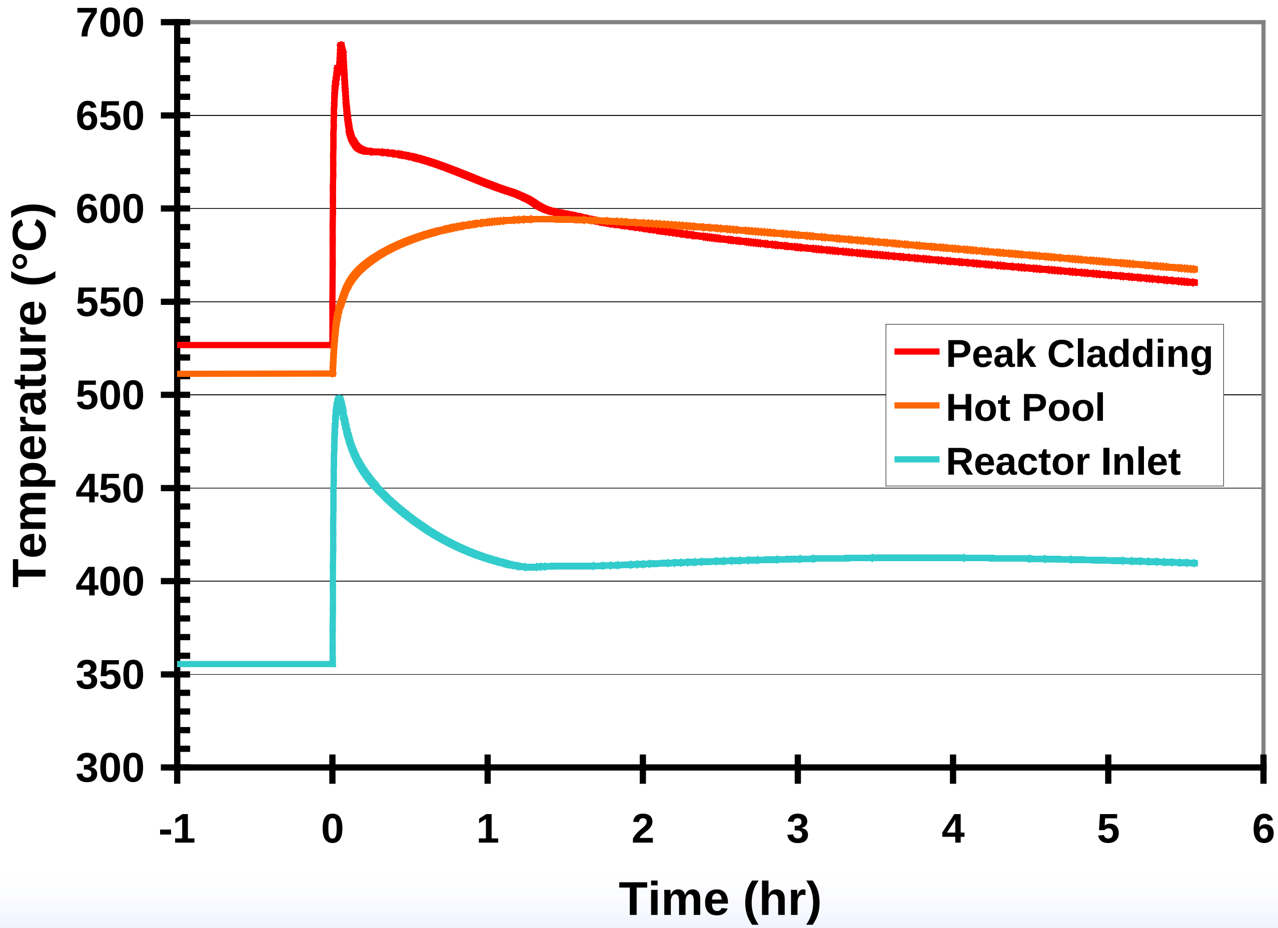
Long Term Temp. Response of the Hybrid SFR to ULOF



Summary

- Inherent safety characteristics of the hybrid loop-pool design are ensured by large thermal inertia of sodium within the hot pool and the buffer pool, and by the innovative passive safety system design.
- RELAP5-3D analyses show that the thermal response of the hybrid loop-pool design during LOFC & PLOFC is very favorable.

Future work for R5 SFR Applications

- Heat conduction and mixing: radial conduction and wire wrapping mixing.
- Transition between laminar & turbulent flow in wire-wrapped rod bundles.
- Thermal stratification modeling in hot & cold pools
- V&V?